Section II: Incorporating M&V into ESPCs

The three chapters in this section provide information on incorporating M&V in a performance-based contract for energy or water conservation projects. The procedures are also applicable to other types of projects discussed in these Guidelines, such as those involving renewable energy, operations and maintenance measures, and cogeneration. The implementation issues addressed include the project M&V procedural steps, the preparation and assessment of the M&V plan, and M&V checklists. The titles of the three chapters in this section are:

- Chapter 3: Overview of M&V Procedural Steps and Submittals
- Chapter 4: M&V Plan Preparation and Assessment
- Chapter 5: M&V Quick-Start Guidelines

3

Overview of M&V Procedural Steps and Submittals

This chapter is an overview of general M&V activities associated with implementing ESPC projects. The information is useful for preparing feasibility studies, requests for proposals (RFPs), performance contracts, and for documenting baseline conditions. The data and analyses performed during M&V development and baseline characterization can be updated and used later in the project.

3.1 M&V Activities

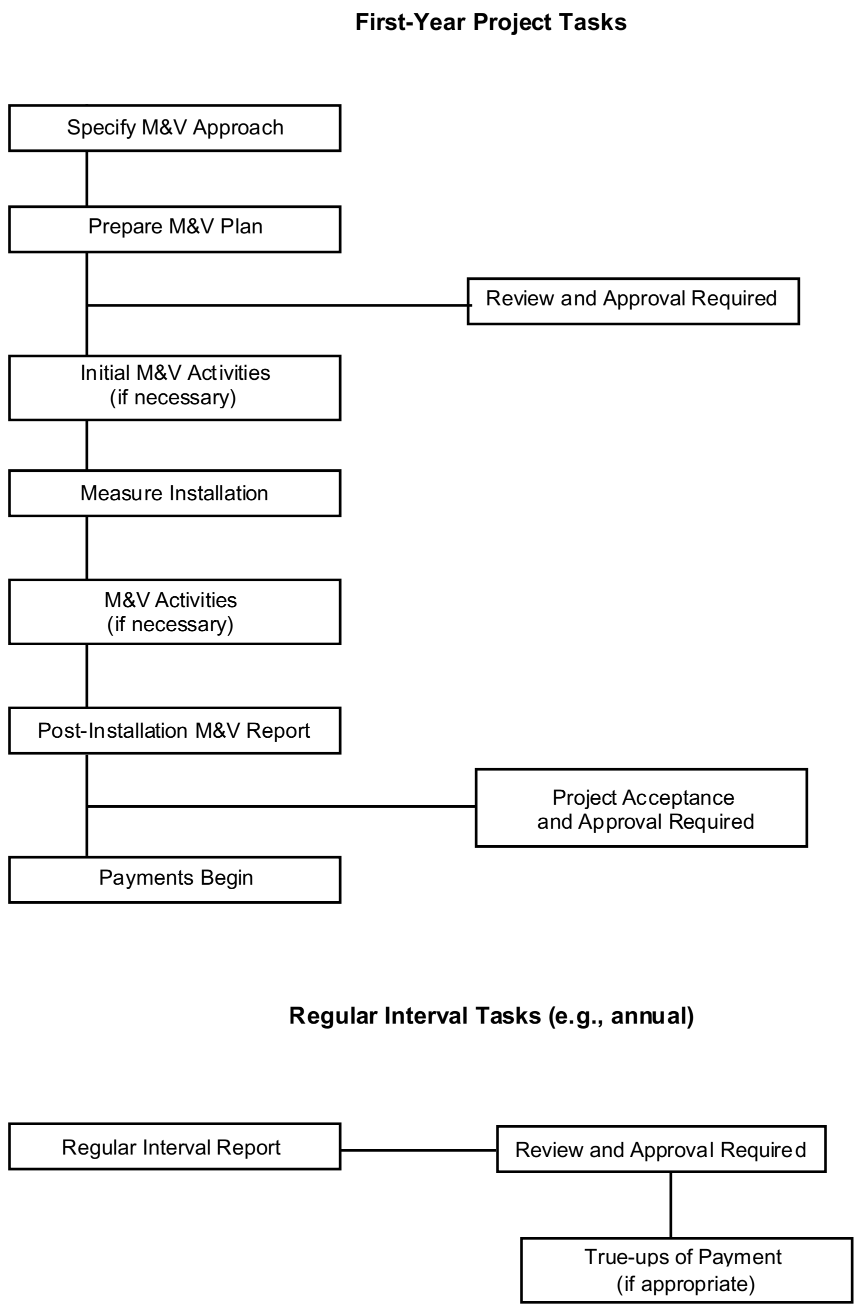
M&V activities fall into the following five areas:

1. Define M&V requirements for inclusion in the contract between the federal agency and the ESCO based on the M&V options and methods defined in other sections of this document.
2. As soon as the project has been fully defined before the contract is signed, prepare a site-specific M&V plan for the project.
3. Define the pre-installation baseline, including (a) equipment and systems, (b) baseline energy use (and cost), and/or (c) factors that influence baseline energy use. The baseline can be defined through site surveys; spot, short-term, or long-term metering; and/or analysis of billing data. This activity may occur before or after the contract is signed.
4. Define the post-installation situation, including (a) equipment and systems, (b) post-installation energy use (and cost), and/or (c) factors that influence post-installation energy use. Site surveys; spot, short-term, or long-term metering; and/or analysis of billing data can be used for the post-installation assessment.
5. Conduct annual M&V activities to (a) verify the operation of the installed equipment/systems, (b) determine current year savings, and (c) estimate savings for subsequent years.

3.2 M&V Activity Details

As a contract is implemented, both the federal agency and ESCO take certain steps with respect to the measurement and verification of each project. Figure 3.1 presents a flow chart of those steps.

Figure 3.1: Overall Project Procedures



The roles of each party in these steps are described in the ESPC delivery order or contract, depending on the type of specific business agreements, risk allocation, and accuracy of desired verification. In general, however, the ESCO provides documentation on equipment and demonstrated savings. The federal agency verifies submittals for accuracy and provides approval so the project can proceed to the next step. The submittals include the project pre-installation report, project post-installation report, and regular interval reports. As part of the review of the submittals, the federal agency conducts site inspections to confirm submittal data.

These steps should apply to most projects; however, some M&V activities (see below) might not be necessary if certain variables, used in estimating savings, are stipulated in the contract. The steps identified above are briefly described in the following paragraphs.

3.2.1 Site-Specific M&V Plan

A site-specific M&V plan that is based on these M&V Guidelines must be defined. This M&V plan will consider the type of ECM or system selected, the desired level of confidence, and the level of accuracy of verification needed.

In some cases, the M&V plan requirement will be included by the agency as part of the RFP. In other cases, the ESCO will propose a site-specific plan to be finalized either before or after execution of a contract or delivery order. The decision as to whether the agency will specify the site-specific plan or the contractor will be asked to provide it could depend on the resources available to the agency preparing the RFP.

The M&V plan should include a project description, facility equipment inventories, descriptions of the proposed measures, energy and cost savings estimates, budget documentation (construction and M&V budgets), and proposed construction and M&V schedules. Details about the contents of the M&V plan are described in Chapter 4.

3.2.2 Initial M&V Activities and ECM Installation

After the federal agency accepts the M&V plan, baseline documentation and analysis is conducted, as needed, and then project installation may proceed. Pre-installation metering is conducted in accordance with the approved, site-specific M&V plan. As soon as the federal agency accepts any required pre-installation metering and analysis, the project can be installed. During metering and project installation, which is done by the ESCO, the federal agency may request progress reports or conduct inspections.

The major tasks associated with M&V work before the ECM installation are as follows:

1. Pre-installation metering is conducted for a period of time required to capture all operating conditions of affected systems and/or processes. If the ESCO is responsible for metering, the federal agency will conduct progress inspections (and/or reports), as required.

2. As specified in the M&V plan, documentation on the results of the pre-installation metering/analysis is submitted to the federal agency for the agency's review and approval.
3. The federal agency notifies the ESCO that project installation may start (or that the pre-installation M&V efforts are not complete and more effort is required by the ESCO).
4. Project installation begins.
5. The ESCO notifies the federal agency that project installation is complete.

If no pre-installation M&V activities are required, project installation approval may be given upon acceptance of the M&V plan and other non-M&V documentation.

3.2.3 Project Post-Installation Report

When the measures are installed, the ESCO notifies the federal agency that the project installation is complete by submitting the project post-installation report. The report includes documentation of the project's complete installation and proper operation (e.g., commissioning) and calculations with energy and cost savings estimates. Post-installation, first-year M&V work may be conducted before or after submitting a project post-installation report but before submitting the first annual report.

Whether first-year M&V activities are conducted before or after submittal of the project post-installation report is defined in the M&V plan. Typically, first-year M&V activities are conducted after submittal of this report so the project installation can be approved quickly and payments to the ESCO can begin. First-year activities may be conducted before the report is submitted if they are simple and can be done quickly.

The federal agency reviews the project post-installation report, inspects the installed project, and inspects any post-installation metering as necessary. The federal agency will either (a) give its approval if the installation and documentation are acceptable or (b) decline its approval if the installation and documentation are unacceptable or issues exist that prevent a review decision. Upon the federal agency's acceptance of the project post-installation report, ESCOs may submit monthly invoices for first-year payment based on savings estimates in the accepted report.

3.2.4 Regular-Interval (Annual) Reporting

Regular M&V activities are conducted periodically based on terms in the M&V plan and the contract between the federal agency and the ESCO. The ESPC program requirements (10 CFR Part 436.37) specify annual verification of savings. Therefore, in almost all cases regular interval reporting will be annual reporting, and it will be referred to as such in the rest of this document. *The ESCO is encouraged, however, to provide quarterly reports on the status of the measures and any available, updated savings reports in order to avoid surprises or delays in the approval of annual reports.*

Annual reports contain the energy and cost savings associated with the project. If the M&V plan calls for metering, the ESCO analyzes current M&V data and submits annual reports for federal agency review and approval. These annual reports typically include measurement-based kWh savings data. Annual report data are used for verifying levels of guaranteed savings and the basis for any required true-up payments. These same data are also used in projecting energy savings for subsequent contract periods, and they are the basis for contract payments in the following period.

The major tasks associated with annual reports are as follows:

1. If the ESCO is responsible for any form of measurements or metering, it notifies the federal agency of the initiation of the metering and any details that require federal agency approval. Metering is then conducted continuously (or for a period of time required to capture all operating conditions of the projects) and/or affected processes. The federal agency can conduct progress inspections of metering, as required.
2. Metering data, data analysis and documentation, and inspection verification documentation is presented in the annual report, or more often, as recommended or required in the M&V plan. Federal facility personnel review and approve the report.
3. Federal facility personnel ensure that the report and verification documentation are complete and accurate and in compliance with the contract and approved site-specific M&V plan.

As stipulated in the contract or delivery order, the federal agency may use the annual report to reconcile payments made to the ESCO for previous billing periods, since previous payments were based on estimated savings that now need to be trued-up to reflect actual savings. The estimates in the report may also be used as the basis for subsequent payments.

4

M&V Plan Preparation and Review

The "performance" aspect of performance contracting is affected by how energy savings are determined. The M&V plan defines project-specific M&V techniques that will be used to determine savings resulting from performance contracting projects. Therefore the M&V plan is one of the most important components of a performance contract. The ESCO typically prepares the project-specific M&V plan and submits it to the federal agency for review and approval.

This chapter provides guidance on preparing and reviewing project M&V plans. General components of an M&V plan are summarized, specific M&V issues and method considerations are explained, and an M&V review procedure is outlined.

4.1 M&V Plan Components

A site-specific M&V plan is required for each site defined in an ESPC agreement. A single project-specific M&V plan can be submitted for multiple sites if, and only if, each project site has the same ESCO, measures, occupancy schedule, use, and energy consumption patterns as the others. In this instance, it is the ESCO's responsibility to document, to the satisfaction of the federal agency, that the project sites meet these criteria.

At a minimum, a project-specific M&V plan *that uses a method described in these Guidelines* must include the items listed in Table 4.1 and Table 4.2. Table 4.1 lists the items necessary to describe the M&V details at the project level. Table 4.2 lists the items necessary to describe the M&V details at the measure level. These items should be repeated in the M&V plan for each measure planned for the project.

It is important to realistically anticipate the costs and level of effort associated with completing metering and data analysis activities. Time and budget requirements are often underestimated. Improved time and budget estimates can be achieved by properly defining the critical factors that affect energy consumption prior to completing the M&V plan. Understanding the project value and costs is necessary to set reasonable M&V goals and accuracy requirements.

A project-specific M&V plan should demonstrate that any metering and analysis will be done in a consistent and logical manner and with a level of accuracy acceptable to all parties. The project-specific M&V plan must be submitted and approved by the federal agency before M&V activities begin. Final resolution of M&V and program design issues are left to the discretion of the federal agency.

Table 4.1: Project M&V Plan Content Components

Category	Content Components	Example
Project description	Project goals and objectives	
	Site characteristics	
	ECM descriptions that include how savings will be achieved	
Project savings and costs	Estimated savings by ECM	
	Estimated M&V cost by ECM	
Scheduling	Equipment installations	
Reporting	Raw data format	Electronic, 15-minute kW
	Compiled data format	Monthly kWh
	Reporting interval	Annually
M&V approach	Accuracy requirements	10% savings uncertainty in savings estimates
	Options used	Option A, B, C, and/or D
	M&V activity responsibility	ESCO conducts metering, analysis, and reporting

Table 4.2: Measure-Specific M&V Plan Components

Category	Content Components	Example
Analysis method	Data requirements	kW, on-hours, temperature
	Stipulated values supporting data	Lighting operating hours equal 4000/year based on metered XYZ building
	Savings calculation equations	
	Regression expressions	Three parameter change-point cooling model
	Computer simulation models	DOE-2

Category	Content Components	Example
Metering and monitoring	Metering protocols	ASHRAE GPC 14P pump multiple point test throughout short-term monitoring
	Equipment	
	Equipment calibration protocols	NIST protocols
	Metering points	Flowrate, RMS power
	Sampling	90% conf./10% prec.
	Metering duration and interval	2 weeks/15-minute data
Baseline determination	Performance factors	kW/ton
	Operating factors	Load, on-hours
	Existing service quality	Zone temps, lumen level
	Minimum performance standards	ASHRAE 90.1 1989
Savings adjustments	Party responsible for which changes	
	Normalized energy-use equations Conceptual approaches	

4.1.1 Preparing Project-Specific M&V Plans Using Other Methods

If the project-specific M&V plan is to be developed using a method that is not described in these Guidelines, the following information should be supplied by the ESCO.

- The reason why none of the M&V methods in the Guidelines are applicable.
- An overview of the method.
- A description of how baseline and post-installation inventories and equipment and system descriptions will be documented.
- A description of any spot, short-term, or long-term metering.
- A method of analysis for calculating savings.

4.2 Metering

M&V consists not only of verifying that new equipment has been installed and has the potential to save energy but also includes measuring energy consumption and energy-related variables. To determine energy savings, some measurement processes need to be conducted to identify the pre-retrofit and post-retrofit conditions. The following sections discuss metering issues that should be considered in preparing a project M&V plan.

In general, a project-specific M&V plan should demonstrate that metering and monitoring will be done in a consistent, logical manner at a level of accuracy acceptable to all parties. Metering and monitoring reports must address exactly what was measured, how, with what meter, when, and by whom.

Calibration of sensors and meters to known standards (i.e., National Institute of Standards and Technology (NIST) standards) is required to ensure that data collected are valid. Project information and metered data must be maintained in usable formats. Both "raw" and "adjusted" data should be submitted to the federal agency with post-installation and regular interval reports.

4.2.1 Equipment

For data collection, storage, and reporting, there are three categories of metering equipment for M&V activities—each with its own advantages and disadvantages. The equipment categories include data loggers, portable loggers, and energy management systems.

Data loggers collect input typically from 3 to 30 transducers. Data loggers can collect information from a range of different inputs, conduct some analyses, prepare reports, and, typically through modems, download information for remote data collection. They tend to be relatively expensive (when transducer and installation costs are included) and, if hard-wired, not very portable, which is an issue when only short-term measurements are required.

Portable loggers collect information about a single variable (such as light fixture on/off status or power consumption of a motor). These tend to be inexpensive per unit, but have limited applications; downloading of data is usually done manually off-site through a connection to a personal computer. Battery-powered portable loggers offer non-intrusive monitoring within an occupied space.

Energy management systems (EMS) are used for controlling systems. These would logically be an excellent option since they are often already in place and have data collection and computing capability; however, caution should be used as many systems are not designed for data storage and reporting, and many operators are not familiar with M&V requirements.

4.2.2 Sensor and Meter Calibration

Sensors and meters used to collect M&V data should be calibrated to known standards (such as NIST). Forms indicating that calibration has been conducted are a required part of the M&V reports.

4.2.3 Metering and Monitoring Protocols

Two types of metering protocols apply to M&V. The first pertains to the M&V procedure and its adherence to M&V protocols (options A, B, C, and D) outlined in this document and based on IPMVP techniques. The second pertains to standardized procedures developed for measuring physical characteristics and metering specific types of equipment. ASHRAE 14P outlines standards for measuring physical characteristics, including power, temperature, flow, pressure, and thermal energy. In addition, ASHRAE 14P lists and briefly describes standards for measuring the perfor- mance of chillers, fans, pumps, motors, boilers/furnaces, and thermal storage. The standardized equipment measurement procedures have been refined specifically for M&V methods for several equipment types. Specifically, ASHRAE 14P Annex E describes these procedures for pumps, fans, and chillers. The methods describe measurement procedures relevant to M&V options A and B.

4.2.4 Metering Duration

The duration of metering and monitoring must be sufficient to ensure an accurate representation of the amount of energy used by the affected equipment both before and after project installation. The measurements should be taken at typical system outputs within a specified (and representative) time period. These measurements can then be used to determine annual and time-of-use energy consumption. The time period of measurement must be representative of the long-term (e.g., annual) performance of the ECM or system. For example, lighting retrofits in a 24-hour warehouse that is operated every day of the year may require only a few days of metering. A chiller retrofit, however, may require metering throughout the cooling season or perhaps for one month each season of the year.

The required length of the metering period depends on the type of ECM or system. If, for instance, the project installation is equipment that operates according to a well-defined schedule under a constant load, such as a constant-speed exhaust fan motor, the period required to determine annual savings could be quite short. In this case, short-term energy savings can be extrapolated easily to the entire year.

If the project's energy use varies across both day and season, however, as with air-conditioning equipment, a much longer metering or monitoring period may be required to characterize the system. In this case, long-term data are used to determine annual energy savings. When the metering or monitoring is complete, the limits of the model used to characterize the system must be defined. For example, if data were taken on the chiller system only when the outside air temperature was between 50°F and 70°F, then the resulting chiller model is probably valid only within the model limits of 50°F to 70°F.

For some types of projects, metering time periods may be uncertain. For example, there is still controversy over how long lighting operating hours must be measured in office buildings to determine a representative indication of annual operating hours. In these situations, an agreement is required between the project parties to determine the appropriate measurement period and accuracy level for the ECMs or systems under consideration.

For some projects, the metering time period can be reduced by forcing a system to go through all of its operating modes in a short period of time. For example, a variable-speed drive ventilation system that is controlled by outside air temperature may require months of data collection to capture a full range of performance data.

But if the control system was over-ridden to force it to operate in various modes, the data collection may only take a day.

If energy consumption varies by more than 10% from one month to the next, sufficient measurements should be taken to document these variances. In addition, changes that will affect the base-year energy consumption adjustment by more than 10% should also be documented and explained. Any major energy consumption variances due to seasonal activity increases or periodic fluctuations must also be monitored. If these variances cannot be monitored for some reason, they must be included in the annual energy consumption figure through a mathematical adjustment agreeable to both parties and documented in the M&V plan.

Energy use can be normalized as a function of an independent parameter such as temperature, humidity, or meals served. Once the relationship between equipment energy consumption and the parameters is established, values of independent parameters measured during the post-installation period can be used to drive the baseline model. Therefore, a project-specific M&V plan should identify critical variables, explain how they will be measured or documented, and discuss how they will be used in the empirical model. Additionally, assumptions and mathematical formulas used in the M&V plan must be clearly stated.

4.2.5 Sampling

Sampling techniques should be used when it is unrealistic to monitor every piece of equipment affected by a retrofit. The sampling procedures outlined in Appendix D provide guidance on selecting a properly sized random sample of equipment for monitoring energy-related factors such as operating hours, RPM, or kWh. The measurements, taken from a sample of equipment, can then be used to estimate the energy-related factors for the entire population.

A successful sample will be sufficiently representative of the population to enable one to draw reliable inferences about the population as a whole. The reliability with which the sample-based estimate reflects the true population is based on specified statistical criteria, such as the confidence interval and precision level, used in the sample design. The reliability of a sample-based estimate can be computed only after the metered data have been gathered. Before collecting the data, one cannot state the level of reliability that a given sample size will yield; however, one can compute the sample size that is expected to be sufficient to achieve a specified reliability level. This is done by using projections of certain values and criteria in the sample size calculations.

Based on the data gathered for a selected period of time, the sample size required may be reduced or increased. If the projections are too conservative, the estimate will exceed the reliability requirements. If these projections prove to be overly optimistic, then the reliability of the estimates will fall short of the requirements, necessitating additional data collection to achieve the specified reliability level. This method of using projections to calculate the necessary sample size is the one adopted for these guidelines.

4.3 Commissioning

System commissioning is the process of ensuring that as-built installed systems are functioning according to their design intent. Commissioning new or retrofit systems in buildings is one method of verifying the performance potential of an installed ECM or system. Thus, commissioning can be part of the M&V process. For complex ECMs, such as HVAC and central plant systems, commissioning is the preferred method of performance verification. Commissioning plans should be developed during the design phase after ECMs and building systems are identified.

If buildings are to realize the full potential of proposed ECMs, adequate resources must be allocated to the commissioning process. This means that time scheduled for commissioning cannot be arbitrarily reduced, and an independent commissioning authority should be appointed. This person or agency should review the design documents to confirm that there is sufficient information to allow the systems to be correctly commissioned and should then oversee the complete commissioning process described in ASHRAE Guideline 1.

In addition to performing building commissioning, the design intent and correct operation of ECMs and systems should be documented for the building maintenance staff. Some ECMs such as natural ventilation, daylighting, nighttime flushing, and use of building thermal mass result in a building that behaves differently than a conventional building does. It is important that the commissioning contractor, building maintenance staff, and occupants understand how the building works. The federal agency may request the ESCO to conduct training sessions for the staff as part of the building commissioning to ensure that the ECMs and systems will be properly maintained and operated.

4.3.1 Standards

These are the minimum suggested standards that should be included in the commissioning process:

- NEBB Procedural Standards for Testing, Adjusting, Balancing of Environmental Systems; Vienna, VA: National Environmental Balancing Bureau, 1983.
- AABC National Standards 1982; Washington, DC: Associated Air Balance Council, 1982.
- ASHRAE G-1 Guideline for Commissioning of HVAC Systems; Atlanta: American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., 1989.
- ANSI/ASHRAE 111, Practices for Measurement, Testing, Adjusting and Balancing of Building Heating, Ventilation, Air-Conditioning, and Refrigerating Systems; Atlanta: American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., 1988.

In addition to the recommendations in these standards, the commissioning authority, as defined in ASHRAE G-1, must be independent of the installing contractor.

4.3.2 Direct Digital Controls Commissioning

Nearly all buildings today (aside from very small ones) have some form of direct digital controls (DDC). Although procedures for checking valve stroke and operation, location, and calibration of sensors are well documented, there is less clarity on commissioning and verification of the software functions and sequence of operations. It is not the intention of this guideline document to define a commissioning procedure for DDC systems. It is vitally important, however, that the system be commissioned correctly, especially if the system will be used to verify energy performance. True system verification requires each point and sequence of operation be checked. For a large and complex building, this may involve two controls engineers for approximately four weeks.

4.3.3 Documenting the Process

Documentation of the commissioning process is critical in performance contracting. Clear documentation of all set points and air and water quantities, as well as any deviations from the design documents are an essential part of the post-installation verification process. Both the commissioning agent and the performance verification agent must review the proposed documentation before commissioning starts. This should ensure that the level of information presented in completed documents is adequate for the performance verification method selected.

4.3.4 Using Energy Management Systems or Data Loggers

Used to collect and analyze data, benefits, and hazards, the building energy management system can provide much of the monitoring necessary for the verification process. The system and software requirements must be specified so that the building EMS can be a useful tool for verification as well as for controlling building systems.

Some parameters may need monitoring for verification, but they might not be required for control. These points must be specified in the design documents. Electric power metering is an example. Trending of small power, lighting, and main feed power consumption may be very useful for high-quality verification. Other functions that can easily be incorporated into the software are automatic recording of changes in set-points. The evaluation team can have a direct read-only connection into the EMS via a modem link. This allows all the trending data to be analyzed and collated by the evaluation team in their office. It is not unusual for many of the trending capabilities required for verification to be incorporated in an EMS; however, often the building facility staff is not properly trained in the use of the system and is unaware of the many additional monitoring and diagnostic capabilities of the system.

4.4 Inspections

Pre-installation, post-installation, and regular interval inspections (e.g., annual) by federal agency representatives may be conducted to confirm the documentation submitted to the federal agency by the ESCO. These inspections, or confirmation visits, by agency representatives are very important. If the federal agency believes that the conditions at the site are not accurately represented by the ESCO's submittals, the ESCO will be allowed to address the problem and make a new submittal. If the ESCO and federal agency cannot agree on site conditions, however, a contract or project may be modified or terminated. The federal agency's inspection personnel do not have the authority to approve changes to contract documents or ESCO submittals to the federal agency. The federal agency's authorized representative (typically, an agency contracting officer) must approve any changes.

4.5 Baseline Characterization

It is not possible to measure the absence of energy use directly. Instead, energy savings must be determined from comparing energy use before and after a retrofit. Therefore, pre-retrofit or baseline characterization is as important as post-installation measurements. The baseline characterization consists of identifying the performance and operating factors that influence energy consumption as well as determining their values through measurements.

A complete baseline characterization is necessary because simple comparison by subtraction of post-installation energy use from baseline energy use is insufficient for accurately estimating savings. A simple comparison does not account for extraneous factors, such as weather and occupancy, that influence energy consumption. Proper assessment commonly involves projecting post-retrofit conditions onto the baseline period. The issues surrounding baseline adjustments are described in Section 4.5.1 below. Additional considerations in defining baseline performance and service quality are presented in Sections 4.5.2 and 4.5.3.

4.5.1 Baseline Adjustments

Baseline adjustments required during the performance period of a contract are a common area of contention in performance contracts. Thus, even if utility bill analysis is used to determine energy savings, a complete and detailed audit (e.g., a detailed energy survey) is required. Examples of situations in which the baseline must be adjusted are changes in the amount of space being air-conditioned, changes in auxiliary systems (towers, pumps, etc.), and changes in occupancy or schedule.

If the baseline conditions for these factors are not well documented, it becomes difficult, if not impossible, to properly adjust them when they change and require changes to payment calculations. For example, if a chiller retrofit takes place in a building with 100,000 square feet of conditioned space, and later (during the performance period) the building's conditioned space is reduced to 75,000 square feet, post-installation energy use would be less and calculated savings would be higher, perhaps inappropriately higher. If there were no records of how much space was originally conditioned, however, the baseline could not be adjusted to properly reflect the amount of “true” savings and how much the ESCO should be paid.

Information about baseline energy consumption that an ESCO submits in the pre-installation report is an *estimate*. This estimate is determined through energy audits and site surveys. It is common, however, for this estimated baseline to change after actual metering data has been collected during pre-installation M&V activities, or if operating conditions change significantly after project installation. This change is called *baseline adjustment*. ESCOs must submit, as part of the M&V plan, a description of how they will adjust the baseline if metering data and/or post-installation operating conditions are different from those used to determine the estimated baseline. The following are examples of why and how baselines are adjusted:

- Changes in weather or occupancy data. Such changes are expected and predictable, so the M&V plan should include procedures for dealing with such changes. These procedures might include (1) recalculating baseline consumption rates using performance-period weather or occupancy data, (2) recalculating performance-period consumption rates using baseline weather or occupancy data, or (3) stipulating typical weather or occupancy conditions.
- Changes in hours of operation or tenant improvements. These changes may be predictable, but because of the numerous unknowns and possible "what-if" scenarios they involve, ESCOs do not need to provide detailed calculation methods covering each eventuality. Therefore, a more conceptual approach is appropriate. In general, an ESCO is responsible for delivering savings that would not have otherwise occurred without the ESCO's intervention. Therefore, decreases in a facility's operating hours or reductions in the amount of conditioned space will not be counted towards savings. In addition, retrofits or tenant improvements installed by a federal agency that are not part of the project cannot be counted toward savings. If, however, increases in operating hours are one of the benefits of the ESCO's project (e.g., lighting retrofit), these can be counted in the savings calculation if agreed to by the federal agency. ESCOs can indicate in their M&V plan (a) which party is responsible for decreases or increases in energy savings associated with different categories of changes, (b) whether or not an ESCO can claim credit for savings associated with different categories of change, or (c) which categories of change are eligible for baseline adjustments.
- Changes in the actual function of a facility, such as a warehouse changing into office space. Such unpredictable changes are addressed in the termination, default, and arbitration clauses contained in the ESPC. Reductions in energy consumption caused by building vacancies, decreased production, and other fundamental operational changes are not considered the basis for savings.
- With Option A, baseline adjustments are less likely to be required since many of the operating or performance factors are stipulated, such as cooling load. This is one reason why Option A can be less accurate but easier and less expensive to implement.
- Option B involves metering techniques. Baseline capacity data are not changed (e.g., lighting wattages, chiller kW/ton, motor kW), but baseline "operating values" can be changed by the use of post-installation monitoring data (e.g., operating hours and ton-hours).

- For Option C, billing analysis, typical values or post-installation values are defined for baseline and post-installation independent variables that influence energy use (e.g., weather and occupancy). It is important to agree in advance on the variables to be used.
- For Option D, calibrated simulation, it is important to agree in advance on how the model will be calibrated and what changes will require a new simulation run. For most retrofit and new construction projects, baseline and post-installation models are calibrated and then run with typical data (e.g., weather data). Thereafter, they are not modified unless major changes occur in the building. Annual verifications are expected, but normally the models do not need to be run again.

4.5.2 Minimum Energy Standards

When laws or federal agency standard practice require a certain level of efficiency, savings *may* be based on the difference between the energy usage of the new equipment and baseline equipment that meets the legal or standard practice requirements. In these situations, the baseline energy and demand consumption must be equal to or less than any applicable minimum energy standards. If this requirement exists, it will be specified in the federal agency's RFP and/or government-defined baseline.

4.5.3 Maintaining Service Quality

The measures installed under ESPC programs should maintain or improve the quality of service provided to the federal agency by the affected equipment or systems. For example, lighting projects that reduce lighting levels must maintain some minimum standards (i.e., the minimum Illuminating Engineering Society (IES) standard for the space's primary use.)

In this document, however, verifying the performance standards is not addressed. Specific facility performance requirements are defined in the RFPs for ESCO services.

4.6 Interactive Effects

It is commonly understood that ECMs and energy systems interact with each other. Reduced lighting loads, for example, can reduce air-conditioning energy consumption but increase heating consumption. Detailed relationships between many dissimilar but interactive ECMs are not known, however, and the methods for measuring interactive effects are not cost-effective for many applications.

For lighting projects, one of the following three approaches can be taken to account for savings associated with interactive effects:

1. Ignore interactive effects.
2. Use mutually agreed-upon default values that are applicable based on the site-specifics associated with building type and HVAC equipment type. The default values can either be assigned on the basis of available information for typical buildings or developed on the basis of computer model simulations for typical building conditions. A critical element of this approach is for the ESCO or federal agency to demonstrate in the baseline lighting survey that the measures or systems are in air-conditioned space. If the space is also heated, the post-installation energy consumption needs to be adjusted upward to account for the increase in the heating load caused by losses in internal heat gains from efficient lighting equipment.
3. Propose a method to measure and estimate interactive effects. The federal agency and/or ESCO will need to agree on the merit and reasonableness of the proposed approach which may include either (a) directly measuring the effects, (b) simulating the HVAC (heating and cooling) interactive effects using a fully documented computer program, or (c) using a utility meter billing analysis approach that captures interactive effects in the total predicted savings. All these methods must be proposed and reviewed on a site-specific basis.

4.7 Calculating Energy Costs

The goal of ESPC is to reduce energy, water, and/or operations and maintenance costs at federal facilities. The M&V plan should be designed to provide energy, water, or operating savings information in such a way that cost savings can be estimated.

For example, energy cost savings will be determined using calculated energy savings and the appropriate cost per unit of energy saved. In most cases the unit cost of energy will be based on a servicing utility's energy rate schedules at the time the project is implemented. The unit cost of energy that will be used in calculating energy cost savings must be defined in sufficient detail in the contract to allow savings to be calculated using each of the factors that affect cost savings. These factors include items such as (for electric bills) kWh saved, kW saved, power factor, kW ratchets, and energy rate tiers.

For performance contracts with cost savings based on peak or billing period load reductions, an M&V method should be selected that provides energy savings data by time-of-use periods corresponding to the facilities' rate structure. For example, at a federal prison, the water heating peak load over a two-minute averaging period might be 252 kW, 228 kW over 15 minutes, or 192 kW using 60-minute time periods of analysis. Considerable error in cost savings estimates are introduced by data that do not correspond to the rate structure (15 minutes, in this case). Thus, it is critical that M&V plans reflect the effects of time-of-use and block rate schedules.

4.8 Reporting

4.8.1 Standardized Forms

Sample survey forms for lighting and motors projects are presented in Appendix C. These forms, which are subject to change, may be required by the sponsoring federal agencies. The forms are based on a particular seasonal and time-of-use utility rate structure. Other rate structures will require different reporting formats for operating hours. Equipment surveys submitted by ESCOs are expected to be comprehensive, accurate (for example, ±5%), and current (completed within a reasonable time before submittal).

Data and surveys submitted should be provided in both electronic and hard-copy formats as specified by the federal agency.

4.8.2 Submitting Metered Data

When submitting an M&V report, ESCOs should provide the data they collect during M&V activities in the formats specified in the M&V plan. Metered data must be provided in formats that are usable by the federal agency and based on products or software that are publicly available. If special software products are required for the reading or analysis of ESCO submittals, the federal agency may reject the data or request that the ESCO provide the software.

Both "raw" and "compiled" data must be submitted to the federal agency in support of surveys, savings estimates, and calculations. For billing analysis and computer simulation M&V methods, electronic and hard copy input and output files must be provided. Compiled survey data must be submitted in both hard-copy and electronic formats using either Lotus 123© or Microsoft Excel©, as specified by the Federal agency.

4.8.3 Communicating M&V Activities to Federal Agencies

ESCOs must notify the federal agency whenever they are about to (a) install and calibrate metering equipment and/or (b) remove metering equipment. Enough lead-time must be given in case the federal agency decides to conduct a site inspection before the equipment is either installed or removed.

Verbal communication concerning changes or acceptance of ESCO M&V submittals is not binding on the federal agency. All submittals, changes to submittals, and approvals must be in writing and signed by an authorized party, as indicated in the ESPC.

4.9 Third-Party Reviewers

Often the ESCO has more expertise and experience than the federal agency in dealing with performance contracts and ECM savings. Therefore, it is often cost-effective and beneficial for an agency to engage third-party M&V professionals to assist in defining or reviewing ESCO-prepared M&V plans and analyzing the results. This helps provide a “level playing field” for negotiation and determination of savings and payments to the ESCO. M&V professionals are typically engineers with experience and knowledge in verifying ECM savings, ECM technologies, and performance contracting. FEMP can help by providing these services or making referrals.

4.10 M&V Plan Review

As noted previously, the level of savings uncertainty and thus effort required to verify both a project's potential to perform and its actual performance will vary from project to project. The project-specific M&V plan should be prepared with these considerations in mind. Section 2.4.2 of the Guidelines discusses some factors that affect the decision of which M&V option, method, and technique to use for each ESPC project. The section below provides a framework for applying these considerations in reviewing the appropriateness of an M&V plan proposed for a federal facility.

4.10.1 Assessment Procedure

A proper M&V assessment includes evaluating the following aspects of the M&V plan to determine if it is reasonable for the specified project:

- Examine ECMs, prioritize by savings amount, and assess error tolerances.
- Review M&V approach for each ECM. Expect diversity in strategies between ECMs.
- Look for documented M&V assumptions and stipulations. Evaluate for appropriateness based on supporting data.
- Assess M&V cost break-down by ECM to determine if level of effort is justified.

Examine ECMs

To facilitate assessing the M&V rigor justified for each measure, it is helpful to rank the measures according to the cost savings anticipated for each. In addition, the uncertainty of the savings associated with each measure should be noted. One simplistic measure of uncertainty is the complexity of the measure. The measure complexity “ranking” can correspond to the measure categories listed in Section 2.5.2 that are ordered by increasing variability of load and operating patterns. A lower position in the list corresponds to a more complex measure. More rigorous (and expensive) M&V approaches are appropriate for high cost savings measures that are complex. Less rigorous M&V approaches are appropriate for less complex measures. In general, the M&V procedures associated with high savings measures should be more closely scrutinized than the low savings measures.

Review M&V Approaches

For projects comprising a variety of conservation measures, one should expect diversity between the M&V approaches proposed for each measure. Of course if all measures have low complexity (i.e., constant load, constant operation), an Option A approach may be justified for each. Otherwise, a variety of options can be expected. In reviewing the M&V approaches, the following questions should be asked:

- Is the rigor (or lack of rigor) associated with the M&V approaches warranted?
- Do M&V methods match the measure savings/complexity priorities?
- Is the model calibration occurring at the desired level (option D)?

Evaluate Assumptions/Stipulations

The engineering assumptions and stipulations that affect energy consumption and savings calculations must be documented in the M&V plan. In addition, the presented values should be supported by data obtained from the manufacturer, similar projects, or measurements. As part of the assessment, the following questions should be asked:

- Are operating hours reasonable? Do they correspond to the project building activities?
- Is the stipulated value subject to sizeable variation?
- Are measurements being made over the full range of operating conditions/loads?
- Do projected savings and baseline values correspond to current utility bill data?

Assess M&V Costs

It is important to couple the measure M&V cost with the estimated cost savings to assess if the level of M&V effort is justified by the level of savings. Therefore, the M&V plan should include a break-out of costs by measure. In assessing the M&V costs, the following should be considered:

- Is the cost of the M&V approach consistent with the projected ECM savings (i.e., both high or both low)?
- Are M&V costs consistent with the level of effort?
- Do the majority of the M&V costs occur up front? If so, are they consistent with the level of effort required up-front?

5

M&V Quick-Start Guidelines

This chapter summarizes materials presented in previous chapters to provide quick-start M&V guidelines. The reader will find the chapter most useful after becoming familiar with the general M&V concepts and procedures presented in Chapters 1–4. The chapter guidelines can be used as a quick reference for checking project-specific M&V plan contents and assessing the appropriateness of the proposed M&V approaches. The figures and tables included in the chapter are listed below. For each, a brief description of its application is provided, as well as the section that contains more detailed information on the topic.

Figure 5.1 Overall Project Procedures
The flowchart graphically depicts the steps involved in the M&V process and the activities usually assumed by the ESCO and the federal agency (ESCO activities on left, agency activities on right). This figure is described in detail in section 3.2.

Table 5.1 Overview of M&V Options
This table provides a quick summary of the characteristics of M&V Options A, B, C, and D. More information about the options can be found in section 2.3 as well as Section III (Option A), Section IV (Option B], Section V (Option C), and Section VI (Option D).

Table 5.2 Ranking ECM Complexity
This table ranks ECM complexity according to performance and operating characteristics (i.e., constant or variable). Higher ECM complexity may justify more rigorous and costly M&V procedures especially if the associated savings are high yet uncertain. Section 2.5 describes selecting M&V methods and rigor in detail.

Table 5.3 M&V Components Affecting Level of Effort and Costs
This table presents considerations that affect the level of effort and cost required to complete the project M&V. The summary is useful for assessing if the estimated M&V cost is justified from the level of effort described. Section 2.4 and Chapter 4 describe such M&V considerations in more detail.

Figure 5.2 M&V Content Requirement Checklist for M&V Approach (Initial Proposal)
This checklist outlines the M&V plan contents that should be included in the initial proposal submitted by the ESCO. The initial proposal may also be referred to as the pre-installation report. More information about M&V plan content requirements are described in Section 2.2 and in Chapter 4.

Figure 5.3 Content Requirement Checklist for M&V Plan and Periodic Submittals (Final Proposal)

Similar to the initial proposal checklist, this checklist outlines the M&V plan contents that should be included in the final proposal or periodic submittals provided by the ESCO. More information about M&V plan content requirements are described in Section 2.2 and in Chapter 4.

Figure 5.4 Guidelines for M&V Plan Review

This checklist outlines issues to be considered in assessing the appropriateness of the proposed M&V plan. The Guidelines also address these issues in Sections 2.5 and 4.10.

Figure 5.1: Overall Project Procedures

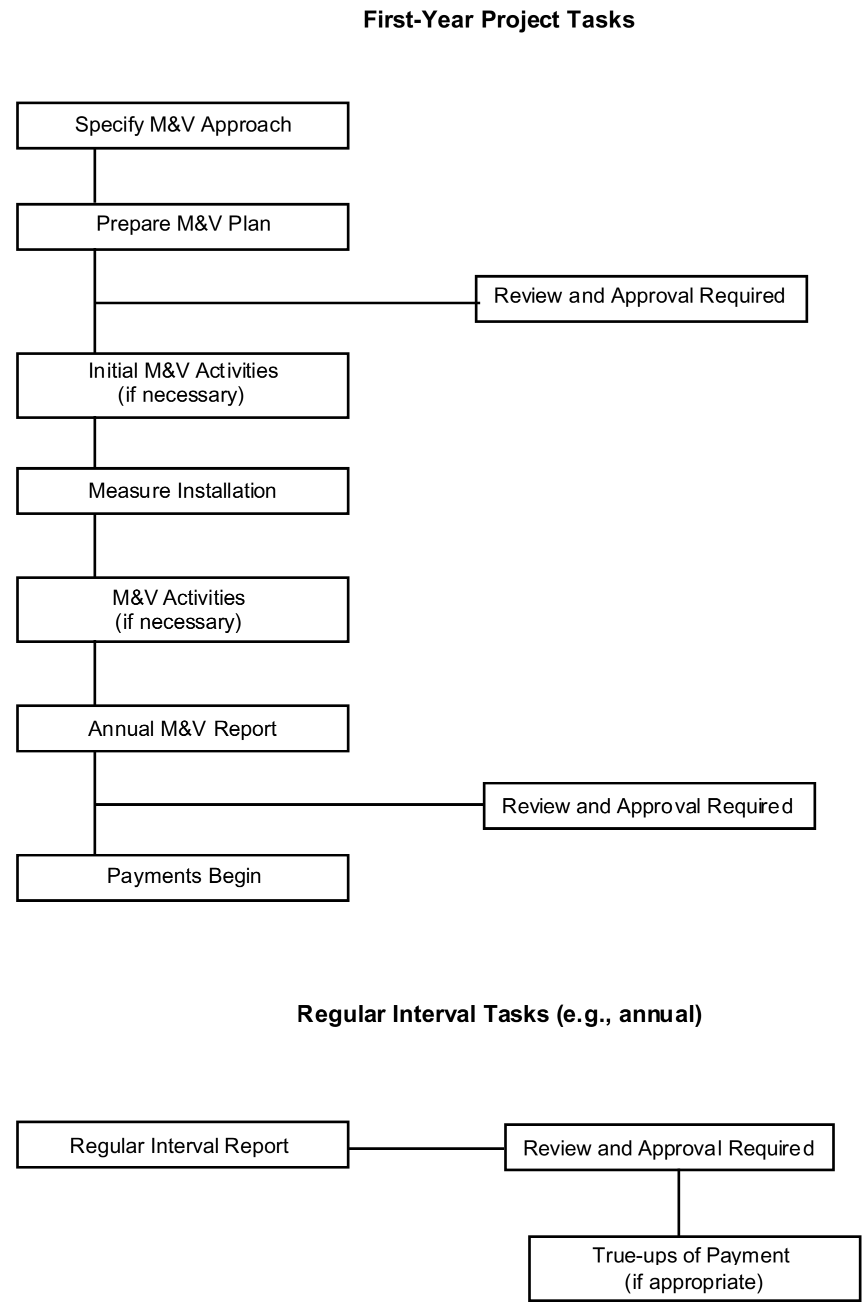


Table 5.1: Overview of M&V Options

M&V Option	Performance and Operation Factors*	Savings Calculation	M&V Cost**
Option A—Stipulated and measured factors	Based on a combination of measured and stipulated factors. Measurements are spot or short term taken at the component or system level. The stipulated factor is supported by historical or manufacturer's data.	Engineering calculations, component, or system models.	Estimated range is 1%–3%. Depends on number of points measured.
Option B—Measured factors	Based on spot or short-term measurements taken at the component or system level when variations in factors are not expected. Based on continuous measurements taken at the component or system level when variations are expected.	Engineering calculations, components, or system models.	Estimated range is 3%–15%. Depends on number of points and term of metering.
Option C—Utility billing data analysis	Based on long-term, whole-building utility meter, facility level, or submeter data.	Based on regression analysis of utility billing meter data.	Estimated range is 1%–10%. Depends on complexity of billing analysis.
Option D—Calibrated computer simulation	Computer simulation inputs may be based on several of the following: engineering estimates; spot, short-, or long-term measurements of system components; and long-term, whole-building utility meter data.	Based on computer simulation model calibrated with whole-building and end-use data.	Estimated range is 3%–10%. Depends on number and complexity of systems modeled.

*Performance factors indicate equipment or system performance characteristics such as kW/ton for a chiller or watts/fixture for lighting; operation factors indicate equipment or system operating characteristics such as annual cooling ton-hours for chillers or operating hours for lighting.
**M&V costs are expressed as a percentage of measure energy savings.

Table 5.2: Ranking ECM Complexity (increasing order of)

Rank	ECM Performance and Operating Characteristics	Load	Hours
1	Constant load, constant operating hours	constant	constant
2	Constant load, variable operating hours with a fixed pattern	constant	variable
3	Constant load, variable operating hours without a fixed pattern (e.g., weather dependent)	constant	variable
4	Variable load, constant operating hours	variable	constant
5	Variable load, variable operating hours with a fixed pattern	variable	variable
6	Variable load, variable operating hours without a fixed pattern (e.g., weather-dependent)	variable	variable

Table 5.3: M&V Components Affecting Level of Effort and Costs

Component	Considerations
Verification of baseline and post-installation conditions	Level of detail required
Metering sample	Size of sample
Metering duration	Time period required to characterize performance or operation; contract term
Metering points	Number of data points required; number and complexity of dependent and independent variables
Metering equipment	Availability of existing collection systems (i.e., EMCS)
Metering accuracy	Equipment accuracy; confidence and precision levels specified for energy savings analysis

Figure 5.2: M&V Content Requirements Checklist for M&V Approach (Initial Proposal)

- ❑ Project site and measures are reasonably defined.
  - ❑ What savings will be claimed? (energy, interactive effects, O&M, rate change, etc.)

- ❑ M&V approach (A, B, C, D from FEMP M&V Guidelines) is defined for each measure.

- ❑ Baseline Equipment and Conditions.
  - ❑ Plan for defining existing equipment (inventory and performance) is described.
  - ❑ Plan for defining space conditions (foot-candles, temps, etc.) is described.
  - ❑ How and why any baseline adjustments will be made is discussed.

- ❑ Post-Installation Equipment and Conditions.
  - ❑ Plan for defining new equipment (inventory and performance) is described.
  - ❑ Plan for defining space conditions (foot-candles, temps, etc.) is described.

- ❑ Annual verification and measurement activities are described.
  - ❑ Who will conduct the M&V activities and prepare M&V analyses and documentation is described.

Figure 5.3: Content Requirement Checklist for M&V Plan and Periodic Submittals (Final Proposal)

❑ Project site and measures are defined.
  ❑ What savings will be claimed? (energy, interactive effects, O&M, rate change, etc.)
  ❑ How will these ancillary savings be treated?

❑ M&V method(s) (chapters), from FEMP M&V Guidelines, is defined.

❑ Details of how calculations will be made are defined. All equations are shown.
  ❑ Provided information shows how collected data and assumptions are used.
  ❑ Energy pricing information and assumptions are defined. (fixed cost, inflated per EIA...)

❑ Baseline Equipment and Conditions.
  ❑ Existing equipment (inventory and performance) is defined.
  ❑ Space conditions (foot-candles, temps, etc.) are defined.
  ❑ Assumptions and stipulations—show supporting information or measurements.
  ❑ How and why any baseline adjustments will be made is discussed.

❑ Post-Installation Equipment and Conditions.
  ❑ Plan for defining new equipment (inventory and performance) is described.
  ❑ Plan for defining new space conditions (foot-candles, temps, etc.) is described.
  ❑ Assumptions and stipulations—show supporting information or measurements to be taken.

❑ Metering equipment is specified.
  ❑ Schedule of metering, including duration and when it will occur, is defined.
  ❑ Who will provide equipment, establish and ensure its accuracy, and perform calibration procedures is described.
  ❑ How data from metering will be validated and reported, including formats, are defined.
  ❑ How electronic, formatted data, directly from a meter or data logger, will be provided.
  ❑ Any sampling that will be used, sample sizes, and documentation on how sample sizes were selected, are defined.

❑ Annual verification and measurement activities are defined.
  ❑ Who will conduct the M&V activities and prepare M&V analyses and documentation is defined.
  ❑ How quality assurance will be maintained and repeatability confirmed is defined.
  ❑ Reports are defined, including what they will contain and when they will be provided.
  ❑ Electronic formats and software programs to be used for reporting are defined.

❑ Initial and annual M&V costs for each measure (totals only).

Figure 5.4: Guidelines for M&V Plan Review

- ❑ Examine ECMs.
  - ❑ Rank cost savings from measures
  - ❑ Assess measure complexity
  - ❑ Assess savings error tolerance
- ❑ Expect diversity of M&V strategies
  - ❑ Stipulations and engineering estimates
  - ❑ Spot/short-term measurements
  - ❑ Continuous measurements
  - ❑ Modeling
- ❑ Assess assumptions and stipulations
  - ❑ Are operating hours reasonable? Do they match the facility's activities?
  - ❑ Is stipulated value subject to wide variations?
  - ❑ Are measurements being made over the full range of loads?
- ❑ Evaluate M&V costs
  - ❑ Is each ECM M&V cost appropriate for the projected level of savings?
  - ❑ Is the cost of the M&V appropriate for the level of effort required?
  - ❑ Do the majority of M&V costs occur up front? If so, are they in accordance with the level of effort required?